



Cross-Technology Solutions to Semiconductor Automation Challenges

The global semiconductor industry is undergoing a new era of rapid expansion. Governments and manufacturers are investing billions of dollars to build and equip new semiconductor fabs to meet current and future demand.

This creates major opportunities — and challenges — for companies supplying the industry with automation technologies. One critical risk is that, during this rapid growth, the development of new production tools and systems will be rushed, leading to inefficiencies and productivity challenges down the road. Semiconductor fabrication tools are some of the most complex manufacturing systems in use today. Tool builders need to concentrate their resources on their core competencies — the lithography, etch and other processes that are the primary function of these production systems.

At the same time, the wafers being processed need to be moved into and out of multiple tools in the most efficient — yet precise — manner possible. Some production processes can require anywhere from 1,500 to 2,000 steps, taking up to six months to complete. These are highly automated processes that require multiple technologies to be engineered and seamlessly integrated. Bosch Rexroth has the complete automation solutions the semiconductor industry needs to solve these design and manufacturing challenges.

Leading tool builders and fabs count on our broad cross-technology automation solutions, combining open controls, sophisticated mechatronics and advanced linear transport. Our custom, pre-engineered and tested systems and subassemblies streamline operations, delivering smooth, precise motion and nanoscale positioning accuracy.

WAFER TRANSPORT MOTION CONTROL CHALLENGES

According to some industry analyses, only a quarter of the processing time for a semiconductor wafer is spent in chambers. The rest is spent transporting the wafers in and out of chambers and between tools. Given these complex challenges, advances in multiple automation processes are needed. For example, wafer transport is one area that must be rigorously controlled to ensure precise, vibration-free motion and avoid damage or costly scrap. Vibration in wafer transport can generate particles that can contaminate the wafer. However, if wafer movement is too slow (to minimize vibration), non-value-added processing time goes

up, reducing productivity and profitability. Thus, wafer lifts and handling devices must balance speed of movement and vibration minimization.

Endpoint accuracy is also critical. Before any process in the vacuum chamber can proceed, the wafer must be perfectly stable and properly aligned. If it takes several additional milliseconds for vibration to dissipate or for the system to reach its precise position, those milliseconds can add up to hours of additional production time.

NEW APP-BASED CONTROL AND DRIVE PLATFORMS

To address these motion control challenges, tool builders can take advantage of new controller and servo drive platforms, offering greater flexibility and precision in motion control. Bosch Rexroth has spent decades refining motion control techniques such as feed-forward algorithms, which predict and compensate for the position and velocity conditions at the end of a motion sequence. Our industry-leading drive and control platforms ensure precise positioning and minimum vibration and settling time in critical applications such as wafer transport.

With ctrlX AUTOMATION, Bosch Rexroth has launched a new generation of automation controls, offering greater scalability and engineering freedom. The ctrlX AUTOMATION platform, which includes ctrlX CORE controllers and ctrlX DRIVE servos, make motion control and automation as easy to use as a smartphone with:

- A Linux real-time operating system
- App-based programming technology
- Full support for EtherCAT
- Web-based engineering

Our open, app-based approach to automation technology provides new engineering freedom. If a specific drive or controller capability is needed, the functionality can be added as an app — just like adding an app on a tablet or smartphone — rather than having to rework the entire automation program.

Successful and efficient subassembly development utilizes a holistic view for design that assesses the mechanics first before forging ahead with the electrical and controls design.



Footprint and facility costs for fabs are some of the highest of any industry. To help tool builders address these challenges, Bosch Rexroth has enhanced its semiconductor-specific controls portfolio with Elmo servo drives. These compact, space-saving drive systems enable extremely fast wafer movement while also controlling the motion axes to minimize settling time – equipping tool builders with control and size capabilities to address their most critical requirements.

CRITICAL ROLE OF PRECISION LINEAR MOTION TECHNOLOGY

Advanced controls are critical to improving wafer transport efficiency and throughput – but they are not the only technology needed for productive wafer handling systems. The linear motion components that physically move wafer stages need matching levels of precision, rigidity and positioning accuracy.

Bosch Rexroth’s extensive portfolio of linear technologies is a key component of our cross-technology automation solutions, engineered to complement the performance of our ctrlX AUTOMATION platforms. Linear technology used in wafer transport assemblies must demonstrate high levels of mechanical stiffness, which is why we offer linear systems with housings made of machined steel. These precise, compact linear axes minimize deflection and ensure high accuracy in both travel and positioning.

For semiconductor tool applications, Rexroth ball screw drives provide superior stability and control. They are ultraefficient at converting rotary motion to linear motion, offering a unique combination of high rigidity, high precision and fast travel speed, while also maintaining the necessary cleanliness.

When considering linear guide systems, it’s important to assess the smoothness of ball recirculation inside the bearing block as it travels along the linear guide. Applications at the very high end of the accuracy spectrum can be adversely affected by even minute pulsations of the balls as they travel through the bearing block. Leading linear module suppliers incorporate guides that optimize the recirculation at key transition points, providing extremely smooth and consistent motion as the balls circulate.



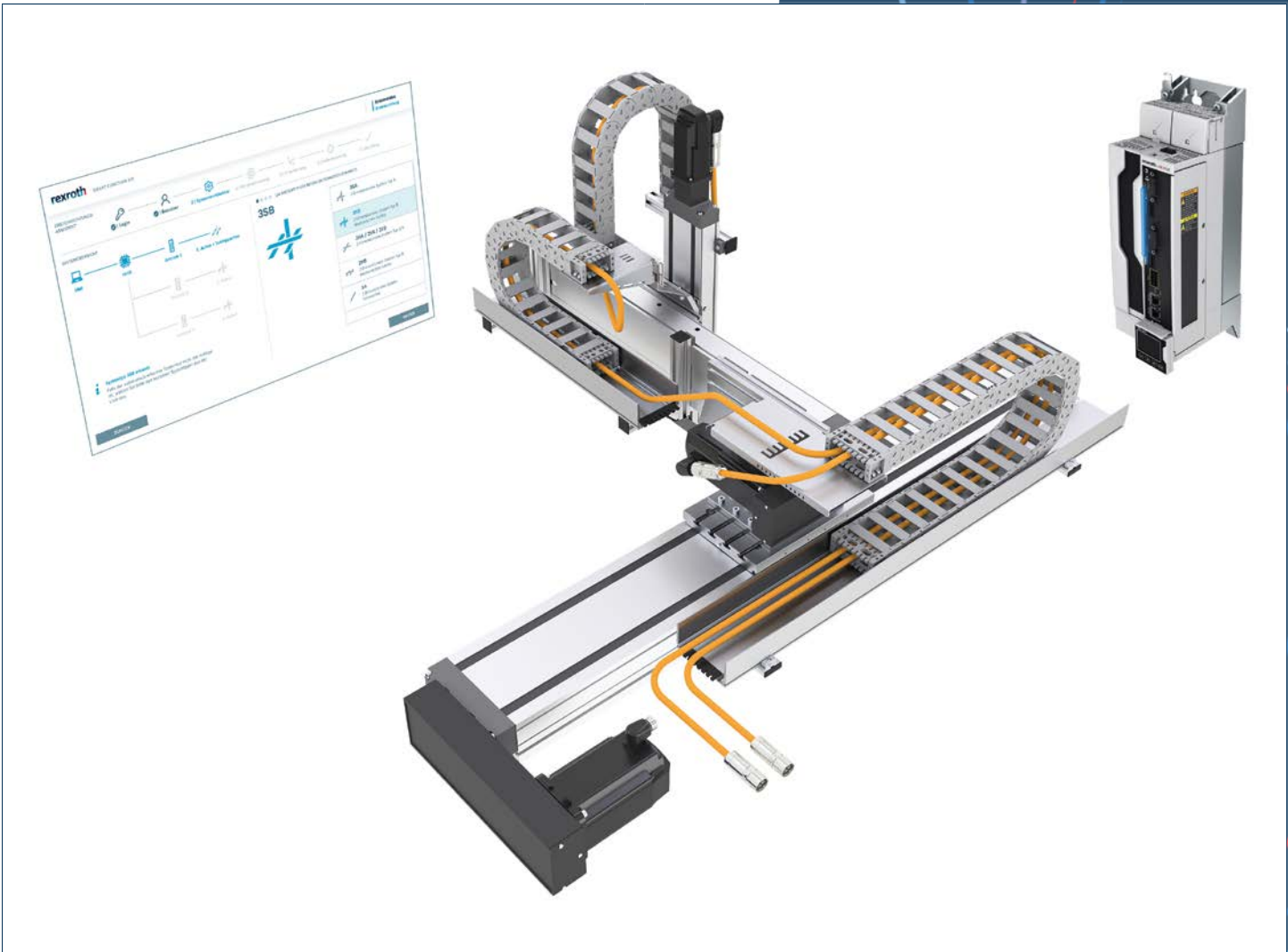
Tool builders and fab operators work with experts to create custom mechatronic assemblies, like this wafer lift assembly from Bosch Rexroth: an efficient, space-saving design that exceeded the customer’s target of five million cycles while providing a 30 percent cost reduction.

CUSTOM SUBASSEMBLIES OFFER COMPLETE TRANSPORT SOLUTIONS

For semiconductor industry tool builders, intense competition and demand for new systems challenge them to move forward with engineering and build cycles as rapidly as possible. To do this, the tool builders need to concentrate their engineering resources on the cutting-edge technologies at the heart of their tools. As a result, tool builders more frequently turn to automation experts like Bosch Rexroth to handle the development of custom wafer transport assemblies that draw on broad, proven technology portfolios.

For example, Bosch Rexroth developed a fully integrated wafer lift assembly combining compact servo drives, motors, controller and ball screws to fit within the tight spaces of a wafer processing tool. The space-saving design reliably exceeded the customer's target of five million cycles while providing a 30 percent cost reduction versus a version the tool builder was trying to design and develop in-house.

At Bosch Rexroth, successful and efficient subassembly development utilizes a holistic view for design. For example, understanding how mechanical elements can affect the motors and controls helps avoid problems later. If a design is based around a specific motor without first considering the mechanics, larger mechanical components may be required to handle the motor torque or inertia. This can result in "overspecification," when a smaller motor and smaller mechanical components could have been used if the mechanics had not been designed around a specific motor.



The Smart Function Kit for Handling uses a "plug-and-produce" concept to simplify mechatronics development. Online selection tools let tool builders and system integrators quickly size and select all their key linear modules, motion control, drives, motors, cabling and more to create a complete solution, all ordered and delivered as a single product.

That is why cross-technology subassemblies like wafer lifts and wafer stages developed by Bosch Rexroth size the mechanical and electrical components together to achieve an inertia ratio that is acceptable for the application's dynamics and precision. Our portfolio also makes it easier for us to develop these automation solutions because the system components come from one source, whereas other subassembly builders may need to source components from multiple suppliers.

If these third-party suppliers don't have experience in the unique requirements for semiconductor tools, problems may arise. For example, if the lubrication used in the ball screws is not cleanroom certified, the lubricant could release contaminants that can ruin wafers, costing tens of thousands of dollars.

Over time, a tool may require some modifications due to new motion control requirements or the need to substitute a part due to supply chain issues. As a custom subassembly manufacturer with full control over its manufacturing and supply chain, Bosch Rexroth has established extensive semiconductor industry resources and expertise. These include knowledge of best practices, such as copy-exact, that let us test, document and validate any modification to a design so that the tool builder can install the updated version with full confidence in its performance.

NEW OPTIONS FOR HANDLING AND CONVEYANCE IN FABS

Along with custom subassemblies, there are ways for semiconductor fabs to improve throughput and efficiency by taking advantage of new linear Cartesian handling platforms and linear motor-based conveyors. Bosch Rexroth has been driving innovation in both types of technologies, to support complete automation solutions that make maximum use of our unique cross-technology portfolio.

For example, our Smart MechatroniX family of systems includes the Smart Function Kit for Handling, which is built around a "plug-and-produce" concept proven to simplify development of Cartesian handling systems. It features online selection software that lets tool builders and system

integrators quickly size and select all their key components – linear modules, drives, motors, cabling and more – to create a complete handling solution delivered as a single product. The Smart Function Kit for Handling also comes with commissioning software for automated drive recognition and utilizes drag-and-drop motion sequences pre-configured for a range of functions, along with digital twin capabilities for programming efficiency.

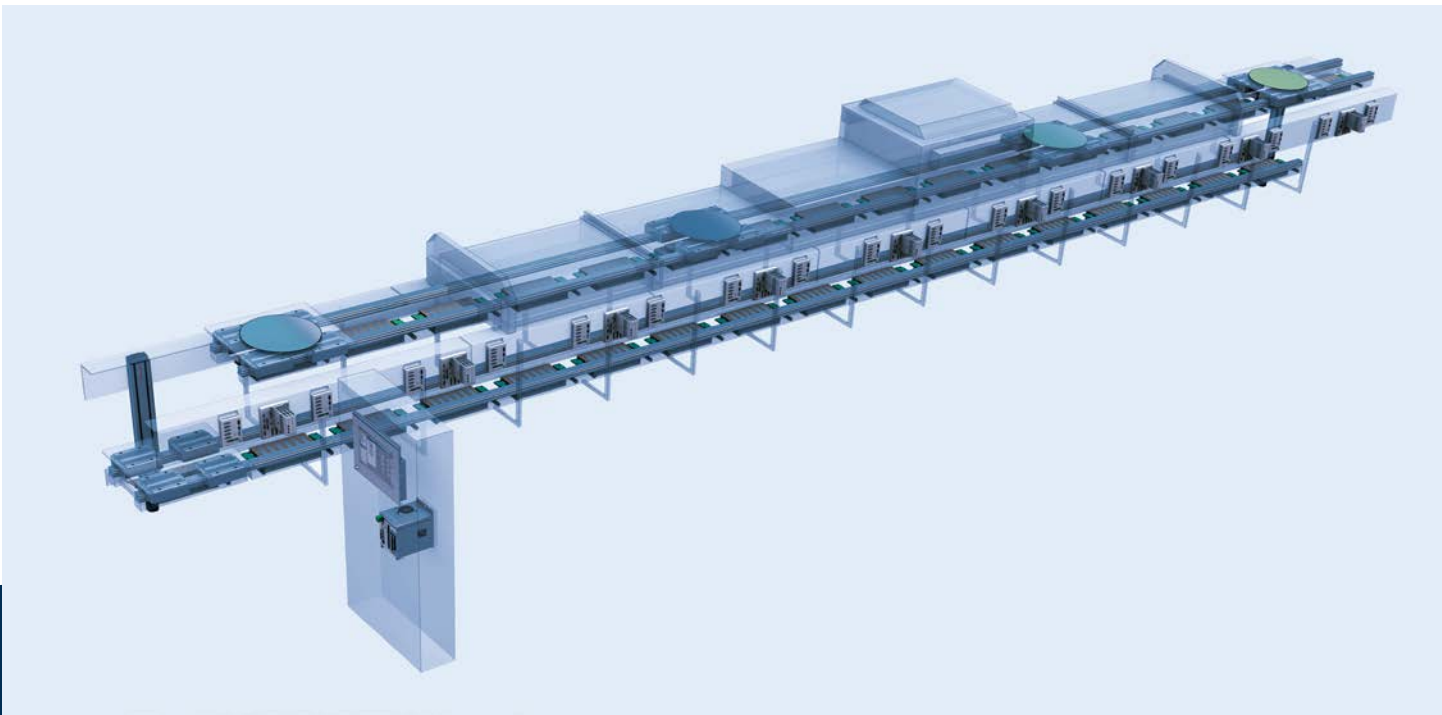
For fab operations with multiple vacuum chambers, the Rexroth Flexible Transport System (FTS) is an innovative linear motor transport platform with an external noncontact motion system that offers an alternative to traditional conveyors. Coils mounted outside the chamber provide drive power for magnetic carriers inside the chamber, offering the precision, feedback and control of linear motors without having cables pulled into the vacuum chamber. The FTS also allows individual carriers to move independently for specialized processing needs.

BENEFITS OF A CROSS-TECHNOLOGY APPROACH

When building wafer transport and handling solutions that can accommodate the precision and control needed in semiconductor manufacturing, partnering with an expert like Bosch Rexroth with a comprehensive automation portfolio can help speed the development of these critical process systems.

A partner like Bosch Rexroth, with proven experience developing custom semiconductor subassemblies, has the right combination of technologies and engineering expertise to resolve potential design complications in a new tool's requirements. We can engage the appropriate engineers to solve specific issues and choose the right products from our cross-technology portfolio, shortening the time it takes to procure, build, test and deliver the best automation solutions for the application.

For fab operations with multiple vacuum chambers, linear motor transport tools like the Flexible Transport System feature external noncontact motion and independent movement of multiple carriers for specialized processing needs.



Bosch Rexroth Corporation

14001 South Lakes Drive

Charlotte, NC 28273

Phone: (800) REXROTH

(800) 739-7684

info@boschrexroth-us.com

www.boschrexroth-us.com

Contact for further information and support:
info@boschrexroth-us.com

 www.facebook.com/BoschRexrothUS

 www.twitter.com/BoschRexrothUS

 www.youtube.com/BoschRexrothUS

 www.linkedin.com/company/bosch-rexroth